2017 International Nuclear Atlantic Conference - INAC 2017
Belo Horizonte, MG, Brazil, October 22-27, 2017
ASSOCIAÇÃO BRASILEIRA DE ENERGIA NUCLEAR – ABEN

Agência Brasileira do ISBN
ISBN 978-85-99141-07-6

A COLLABORATIVE VIRTUAL ENVIRONMENT FOR TRAINING OF SECURITY AGENTS IN NUCLEAR EMERGENCIES

Sara I. Fernandes[1], Cláudio A. Passos[1], Marcio H. Silva[1], Paulo Victor R. Carvalho[1], Ana Paula Legey[1], Antonio Carlos Mol[1], Daniel M. Machado[1], André Cotelli[1] and Tiago L. Rocha[1]

[1] Departamento de Realidade Virtual (IEN / CNEN – RJ)
Cidade Universitária - R. Hélio de Almeida, 75
Ilha do Fundão, Rio de Janeiro - RJ, 21941-614
mol@ien.gov.br

ABSTRACT

In face the recently observed security menaces related to terrorist actions and natural disasters, there is a need for a major qualification and training of the agents responsible for avoid any problems regarding to abnormal conditions. In the conventional training procedures, however, field simulations are associated to logistical and operational constraints regarded to the execution of the tests which can expose the user to risk.
On the other hand, the use of virtual simulations provides an alternative to such limitations besides of promote the qualifying of professionals with a great reliability. For this reason, this paper proposes the development of a collaborative virtual environment that will be used to prepare the security agents on identifying individuals suspected of carrying radioactive materials.
The development of the virtual environment consisted on modeling using Autodesk 3ds Max, where the scene itself and the scene objects were modeled besides the terrain creation and basic features programming using the Game Engine Unity 3D. In the Engine Game were included radiation detectors and avatars. The security agents were able to communicate to each other by means of auxiliary external tools like a headset software that makes possible the communication, coordination and cooperation required for an effective collaboration.
Experimental tests of the virtual simulations were performed with the participation of CNEN radiological protection agents and collaborators.
The tests have shown that the proposed method can contribute to improve the training results of the basic collaborative skills required for a CNEN agent in an emergency situation without the need to espose him to any kind of risk. In face of that, we hope that it can contribute to minimize the demand for qualified security professionals.
Keywords: radioprotection, physical security, virtual reality, simulator, collaborative virtual environment game.

1. INTRODUCTION

In recent years can be seen a growth of large events with membership characteristics of tourists from all over the world, among the events stands out the Olympic Games and world cup. The increase of terrorist acts indicates that there are complex actions to be taken by professionals and rescue workers. Concerned about this situation, governments and global organizations are creating emergency management to ensure the normality of these events.

Emergency management at an event is a complex problem involving unpredictable situations. This complexity enhances the operational contexts of organizations and, consequently, those involved in performing various tasks from activities that require intense cognitive effort need to adapt to maintain productivity and performance at satisfactory levels, which often prevents them from Reflect on the results of their actions and learn from them. Under this environment, organizations such as military, nuclear power, disaster response, air traffic logistics planning, space mission control, and others, increasingly use simulation exercises to train their professionals [1].

Simulation exercises should be designed to address the cognitive skills that must be developed to respond to an emergency. The purpose and scope of these exercises may include training of responders, providing practice opportunities to learn about new threat situations, evaluating new technology systems, improving teams, identifying critical decisions, improving coordination, and putting all evidence to the test Planning conceived.

Training in field simulation is very difficult to implement in practice, since it involves large operational logistics, considering the availability and displacement of several agents from different agencies, the allocation and displacement of emergency resources (which may be necessary for an Emergency), interdiction of urban areas, among others. In order to have agents that are perfectly skilled and able to handle situations of adverse emergencies, and that are capable of dealing with hostile actions satisfactorily, thus ensuring that events occur in an orderly and safe manner, a frequent periodicity of these field training is required. This makes operating costs sky-high by considerably limiting the effective amount of training agents.

This is reflected in the search for new technologies to simulate, explore and test new forms of operations aimed at solving difficult situations or preventing future emergencies [2, 3, 4]. For this it is necessary the creation of tools that approach the methods and techniques to assist in the pre-training of security agents. One of the possible ways of performing this training is by using virtual reality [5]. This work proposes the development of a simulator in the form of a virtual collaborative environment (CVE) that presents an alternative method of command and control training to improve the performance of security agents. As a case study, this article proposes identification exercises and approaches of suspects who carry radioactive elements. The proposed model uses modern Virtual Reality technology in the area of immersion and interaction (essential for command and control centers), providing greater involvement of trainees without having to subject them to risk. The environment chosen for the application of this training is based on space for large events in the city of Rio de Janeiro, the Maracanã football stadium.

2. VIRTUAL REALITY

The first Virtual Reality devices were used by the American Air Force after the end of World War II, with flight simulation purposes for pilot training. Currently RV can be commonly found in a wide variety of applications, such as virtual modeling, ergonomic studies, widely used in the entertainment industry to create games, movies and animations. And, also, in diverse scientific fields [6].

In recent years Virtual Reality (VR) has become popular as a new trend of human-machine interaction, and has consolidated itself as a tool that allows the user to explore and interact with information in a three-dimensional environment generated in the computer, as if it really Was part of the virtual world [7].

2.1. Virtual reality in physical security virtual

Simulating emergency situations in VR allows potential initial mistakes of people and teams to be made in the virtual world, and perhaps improve safety drills or operational training, without risk to people involved [8]. Therefore, this technique allows training for rare and unusual situations, such as an incident of suspected radioactive contamination in a football stadium. This operation involves collaborative actions where there must be collaborative actions such as coordination, communication and cooperation between agents, field progression techniques, evacuation, isolation and analysis of the suspect area, material and individual, and so on.

With the use of VR training the chance of success of the actions increases significantly because the agents will have access to a much larger number of information than the analysis of a plant or photos of the place could provide. Another important factor is the possibility of repeating the procedures as many times as necessary, allowing the development of the motor response (motor program) of the agents, thus reducing the reaction time of the agents when encountering a similar scene after being trained.

In the field of physical security, the RV allows the improvement of training of the security agent [8], such as the work in the area of physical security in nuclear installations of police, which has been carried out in Brazil and in other countries, such as Example, China, Germany [9] and Cyprus [10].

3. COLLABORATIVE SYSTEMS

Collaborative systems allow interaction between individuals and groups to perform tasks and are used to refer to the terms "groupware" and "CSCW" (Computer Support Supported Cooperative Work). Groupware is defined as computational systems whose interface is capable of providing a shared environment to support groups of people to engage in a task, thus encouraging Communication, Collaboration and Coordination among them [11]. The great challenge of these applications occurs when collaborative activity begins to occur in real time and especially in virtual collaborative environments shared by remotely located users.

In short, collaboration requires team members to exchange information (communicate), organize their actions (coordinates), and operate together in a shared space (cooperate), meeting the needs of command and control centers. For the development of the training structure for command and control, we use the 3C collaboration model [12, 13, 14].

3.1. Collaborative Virtual Environments

Driven by the rapid development of computer networks, Collaborative Virtual Environment (CVE) is the evolution of Virtual Environments to support multiple users participating in the same interaction. CVEs have come to stand out as an attractive way to support computer-assisted activities in a wide range of fields such as medicine, education, entertainment, among others [15, 16, 17]. Characteristics such as group formation, communication, information sharing, multiple views of the same information and awareness and perception of situation put the CVE from the CSCW perspective.

3.2 Exercises performed in virtual collaborative environments

Collaborative virtual environments designed for multi-user gaming and military simulations are examples of collaborative applications that require sophisticated coordination mechanisms to ensure the fulfillment of tasks [18].

Response and rescue organizations train and conduct exercises for a variety of reasons to improve individual training and system capabilities. In some cases, training is part of regulatory requirements such as the Nuclear Regulatory Commission, or licensing to practice as with airline pilots and medical personnel. The fundamental difference is the way they train. The Federal Emergency Management Agency (FEMA) and the Department of Homeland Security (DHS) emphasize that the driving force of any exercise program is to use training exercises to improve the readiness and capabilities of an organization. Exercise classes provide a means to evaluate plans, procedures, and operations, cultivate teamwork, and illustrate the ability of an organization or community to prepare for disaster events [1].

Key goals for exercise are to better establish roles and responsibilities, improve coordination among agencies, identify gaps in resources, enhance individual performance skills, and identify opportunities for improvement.

Considering the difficulties encountered in the command and control centers of bringing together agents from different agencies in the same location and that practical training in live exercises becomes expensive and difficult to organize [19], training based on simulated computer environments is suggested to be An efficient way of generating resources to complement the traditional exercises [20], even replacing them.

A simulated exercise can be defined as a hands-on training and is able to simulate an emergency scenario in which plans are put into place to combat anomalous events so that it is possible to conduct training and assessment of teams facing a real danger situation [21].

In the area of training and simulation, an example military application simulates a combat aircraft, developed by British Aerospace for training British cadets [22]. Virtual reality is also used to train radar operators [23] and to train soldiers in the operation of tanks. The last work is linked to the SIMNET project developed by DARPA (Defense Advanced Research Projects Agency) that provides a distributed virtual environment with several remote virtual simulators interconnected, exchanging information and keeping the environmental description updated [8, 24]. Figures 1 and 2 illustrate two examples of collaborative exercises used in CVE developed in this work.

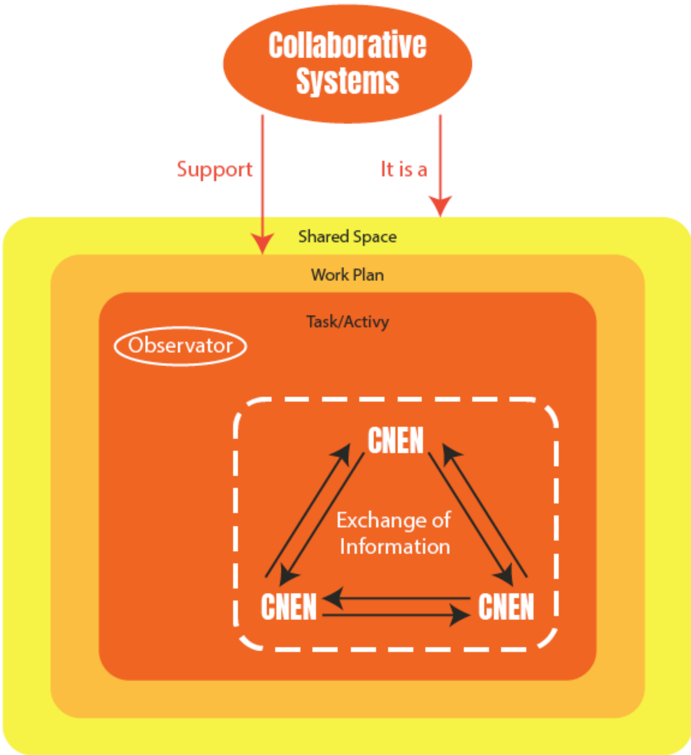

Figure 1: Procedure for the identification of radioactive materials used by CNEN agents during the FIFA 2014 World Cup.

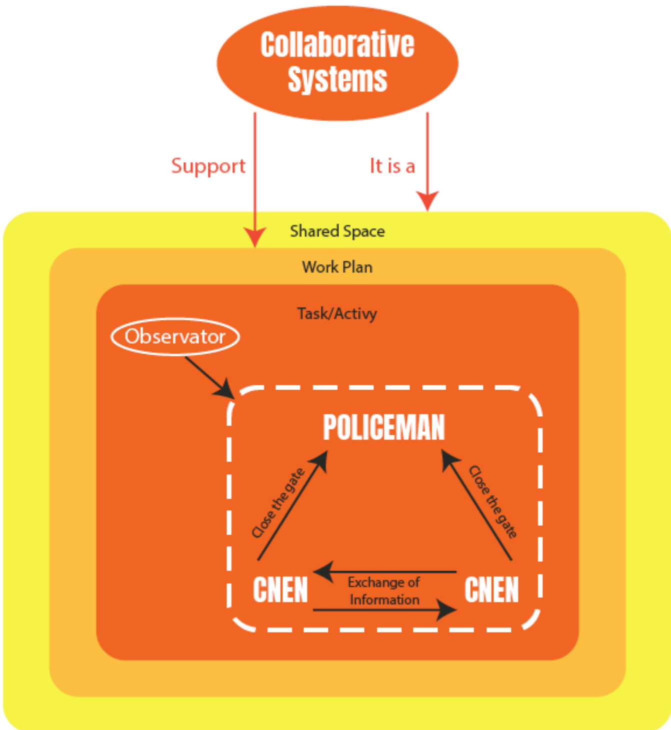

Figure 2: Procedure for the identification of radioactive materials used by CNEN agents during Rio 2016 Olympic Games.

4. METHOD

The proposed method for the development of this work is divided into five stages. The first step is called Modeling the Environment. For this, the software was used to create terrain and Autodesk 3Ds Max software to model the avatars, the scenario based on Maracanã Stadium and objects, such as the statue of Bellini. The second step, called Functionality Implementation, involves inserting functionality into the core of the Unity. The functionalities were the radiation detection algorithm and automata functionality of avatars. The third step is to develop scenarios to simulate ways to approach individuals suspected of transporting radioactive materials. The fourth step is to implement the CVE for drill execution in the use of these scenarios. The fifth step called Evaluation consists of a questionnaire answered by agents immediately after the training session with questions about using CVE as a training tool and as a way to train collaboration problems. Figures 3 and 4 show images related to the modeling scenario and numbers 5 and 6 show CVE images after it has been completed.

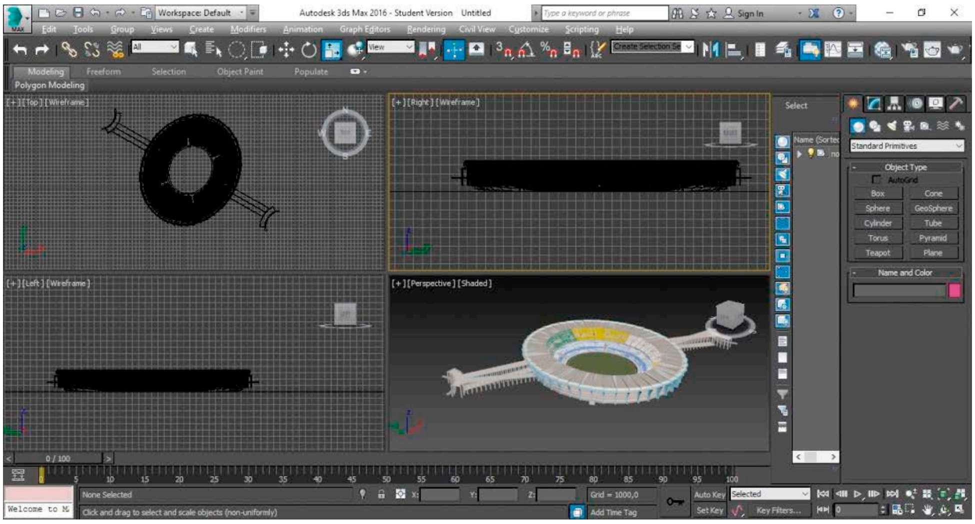

Figure 3: Modeling the Maracanã Stadium.

Figure 4: Topographic image added on the terrain created in Unity.

Figure 5: Menu to choose a character of CVE.

Figure 6: CVE for security training based on Maracanã stadium.

Avatars are used to provide interaction between the user and the developed environment. In this work besides of the generic avatars representing the audience, there are also specific avatars representing the security agents and suspects. Depending on the ongoing implementation, these avatars can act in different ways such as firefighters, police officers or agents from the local command and control center, according to the user's will. In Brazil, CNEN is the Federal organization responsible for deal with problems related to nuclear issues. As we intend to carry out simulations related to command and control center exercises, we focus on the training of scenarios that require a lot of collaboration between agents.
The table 1 show so exemplified the functionalities present in the CVE for the training of agents and the table 2 shows the functionalities of the suspect (s).

Table 1 - Functionalities available to agents

Agent	Functionalities
	• Measure radiation to identify suspects. • Address the suspects • Communicate with agents of their own agency and other agencies
	• Use the radiation detector. • Communicate with agents of their own agency and other agencies
	• Arrest suspect • Surround and evacuate area(s) with bars • Organize queue (s) with bars • Communicate with agents of their own agency and other agencies
Watcher (no avatar)	• Select the camera of the agent that you want to watch • Communicate with the agent(s) • Coordinate agents

Table 2 - Functionality available to suspects

	• Transporting radioactive material • Communicate with other(s) suspects)

The table 3 describes the scenario, specifying its purpose and highlighting the skills that are expected to enhance in the training.

Table 3 – Scenarios descriptions.

	Descriptions
Scenario 1	One person (avatar controlled) carrying radioactive material of low dose goes up the ramp of the stadium following by the other avatars (automata). The person passes by the entry, and when he see radioactivity detection barrier (composed of two agents of CNEN, each one in one side of the ramp), he tries to pass as far as possible from the security agents. He passes through the first barrier and sees a second barrier, consisting of one agent CNEN in the middle of the ramp. Aiming to pass as far as possible from the security agent, he walks over to one side of the ramp.

Scenario 2	One person (avatar controlled) carrying radioactive material of high dose goes up the ramp of the stadium following by the other avatars (automata). The person passes by the entry, and when he see radioactivity detection barrier (composed of two agents of CNEN, each one in one side of the ramp), he goes through the center of the ramp to pass as far as possible. He passes through the first barrier and sees a second barrier, consisting of one agent CNEN in the middle of the ramp. Aiming to pass as far as possible from the security agent, he walks over to one side of the ramp.
Scenario 3	Two persons (controlled avatars) carrying radioactive material of low dose goes up the ramp of the stadium following by the other avatars (automata). When observe detection barrier made up of a CNEN agent on each side of the doorway, they separate. One continue to walk by the ramp to pass as far as possible to the agents, and the other just stops and starts walking when the first approaches the barrier. Overcome the first barrier, the persons reach a second barrier, consisting of an agent CNEN centered on the ramp. Aiming again to go as far as possible from the agent, the suspects walk separately toward the side of the ramp.

The table 4 shows the descriptions of the skills that are expected of the user after training.

Table 4 - Skills required in scenarios

Developed skills	Description
Collaboration	• Promote collaboration and work well with others to effectively accomplish the mission. • Keep informed the other officers about what is happening • Ensure integration with other agencies agents
Communication	Provide a clear verbal communication, concise, complete and correct to the other agents participating in the event
Internal coordination	Provide coordination between agents and new strategies of the identification.
External coordination	Provide coordination between agents and new strategies of the identification

5. SIMULATION

For the realization of the training exercises (drills) with CVE it was adopted the same procedure used during the games of the 2014 FIFA World Cup for the three first sessions and the procedure used during the Rio 2016 Olympic Games for the session fourth. The table 5 describes the procedures.

Table 5 – Procedures used to identify suspects.

Procedure used during the games of the 2014 FIFA
Two radiation barriers monitored by CNEN agents were created, the first positioned five meters after the metal detector and the second positioned 20 meters after. This barriers was not perceived by most spectators, because agents, positioned in strategic places, did not offer any kind of impediment to the progress of people.
Procedure used during the Rio 2016 Olympic Games
As soon as a CNEN agent detected the presence of radioactive activity, the national security force was contacted to block the passage of all people, until the hazardous material (in this case a nuclear source) be found, thus preventing the suspect from entering the stadium.

The drills were performed by a group of three specialists employees in the radiological inspection service of CNEN and two students who took part in the development of virtual environment. The employees were invited to contribute using their experience in real situations and thus help make the situations analyzed in the CVE as faithful as possible. They were in charge of controlling the security officers who made up the barriers. Before the start of the simulation the participants (with their computers connected on the local network) had twenty minutes interaction with the CVE for adaptation. Each of these CNEN agents has more than 15 years of experience on dealing radioactive safety.

6. RESULTS

The tests comprise a number of 24 simulations divided into four sessions, six in the first session, eight in the second, six in the third and four at the last one. In the first three sessions, the procedure used during the games of the 2014 FIFA and in the last session the procedure used during the Rio 2016 Olympic Games (see table 5). The results are detailed in tables 6 and 7.

Table 6 - The first three session results

Session/ Simulation	Scenari o	Result	Core competency developed observed	Number of Agencies
1/1	1	Fail	Identification of radioactive source	1
1/2	1	Fail	Identification of radioactive source	1
1/3	1	Success	Identification of radioactive source Collaboration and Communication	1
1/4	2	Success	Identification of radioactive source	1
1/5	2	Success	Identification of radioactive source	1
1/6	2	Success	Identification of radioactive source Collaboration and Communication	1
2/1	1	Success	Identification of radioactive source	1

2/2	1	Success	Identification of radioactive source Collaboration and Communication	1
2/3	1	Success	Identification of radioactive source Collaboration and Communication	1
2/4	2	Success	Identification of radioactive source	1
2/5	3	Fail	Collaboration and Communication	1
2/6	3	Success	Identification of radioactive source Collaboration and Communication	1
2/7	3	Success	Identification of radioactive source Collaboration and Communication	1
2/8	3	Success	Identification of radioactive source Collaboration and Communication	1
3/1	1	Success	Identification of radioactive source	1
3/2	3	Fail	Identification of radioactive source Collaboration and Communication	1
3/3	3	Fail	Identification of radioactive source Collaboration and Communication	1
3/4	3	Success	Identification of radioactive source Collaboration and Communication	1
3/5	3	Fail	Identification of radioactive source Collaboration and Communication	1
3/6	3	Success	Identification of radioactive source Collaboration and Communication	1

Table 7 - The fourth session results

Simulation	Scenari o	Result	Core competency developed observed	Number of Agencies
1	3	Success	Identification of radioactive source Collaboration and Communication	2
2	3	Success	Identification of radioactive source Collaboration and Communication	2
3	3	Success	Identification of radioactive source Collaboration and Communication	2
4	3	Success	Identification of radioactive source Collaboration and Communication	2

7. CONCLUSIONS

The Collaborative Virtual Environment (CVE) proposed in this work has managed to reproduce the real training action scenario with a great degree of interactivity and immersion, transferring the user (here represented by CNEN agents with field experience in identification of hazardous materials) to a interactive three-dimensional virtual environment. In such environment, the agents, using avatars, are capable to make decisions and develop collaborative actions, which contributes to promote an additional value for the training procedures. So, the CVE described here has proved to be suitable for training simulations viewing that it was able to represent scenarios quite similar to its real matches referring to potential emergency situations as the ones experienced by CNEN agents during the FIFA 2014 World Cup and Rio 2016 Olympic Games.

The architecture and the virtual environment were developed to add to the training system a greater degree of interactivity and immersion, transferring the participant to a three-dimensional virtual environment, which reproduces the training action scenario and it the user (represented by avatar) should take decisions and develop coordinated and collaborative actions, helping them in their individual and collective development and aggregating a value to further training, since the close of the real environment. The actions imply the movement at the meeting and deviation of physical obstacles and real-time interaction with other users or automata present avatars in the virtual environment, which is influenced by several factors relevant in the real environment, such as sound, visibility and lighting, physical interaction, among others.

The scenarios proposed in the simulations in the first three sessions described above allowed to reproduce the original procedure faithfully, with results quite similar to the ones observed in the field tests. Based on the description of the new approach adopted for the Rio 2016 Olympic Games, a new procedure using the CVE proposed in this work was prepared, aiming to reproduce it. Thus, the aim of this new simulation is to evaluate the suitability of the proposed CVE as an alternative tool for developing new strategies of identification.

After the four sessions, it was evidenced the tool's ability to assist in the development of new training strategies and that collaboration between agents from the same agency or from different agencies showed the importance of collaborative training in command and control exercises.

Finally, important to emphasize that all features implemented in the environment for the scenario of suspected radiological approaches can be reused and / or expanded to several other training scenarios, which makes it flexible and adaptable tool, featuring thus its versatility.

ACKNOWLEDGMENTS

Our thanks to Nuclear Engineering Institute (IEN) for giving in the virtual reality laboratory for the development of the virtual environment and their agents Claudio Reis Santa'anna and Douglas Sales for participating in two training sessions and in the virtual environment improvement tips. We also thank the Osvaldir Paulo dos Santos agent for detailing the approach strategy implemented by the IEN / CNEN during the 2014 World Cup. Our thank the students of College Pedro II, João Victor, Yuri Medeiros and Emmanuela, who were collaborators of the research, participated in the programming of codes and the modeling of the virtual environment.

REFERENCES

1. Voshell, M. G., Planning Support for Running Large Scale Exercises as Learning Laboratories. *The Ohio State University*, 2009
2. Hintze, N., First responder problem solving and decision making in today's asymmetrical environment. *Unpublished master's thesis, Naval Postgraduate School,* 2008
3. Smith, R.; "The application of existing simulation systems to emerging homeland security training needs". *In Simulation interoperability workshop*. Workshop, 2003
4. Baldwin, R. Training for the management of major emergencies. Disaster Prevention and Management: *An International Journal*, Vol 3 Iss:1, p. 16 - 23. 1994.
5. Mol, A.C.A.; Gatto, L. ; Legey, A.P.; Jorge, C. A. F. ; Santos, I. L. . Virtual Simulation of a Nuclear Power Plant's Control Room as a Tool for Ergonomic Evaluation. *Progress in Nuclear Energy (New Series)*, v. 64, p. 8-15, 2013.
6. Grimes, J.: "Virtual reality 91 anticipates future reality", *IEEE Computer Graphics & Applications*, pp. 81-82, November, 1991
7. Kirner, C. e Siscoutto, R.A., "Fundamentos de Realidade Virtual e Aumentada". *Livro do Pré-Simpósio: IX Symposium on Virtual and Augmented Reality*, Petrópolis, 2007, pp. 2-21.
8. Burdea, Grigore C.; Coiffet, P. (2003). "Virtual Reality Technology". 2 ed. New Jersey: *Wiley-Interscience*, 2003
9. Bertram, J.; Moskaulik, J.; Cress, U. Virtual police: acquiring Knowledge-in-use in Virtual Training Environments. In: International Symposium on Virtual Reality Innovation, 1., Singapura. Proceedings… Singapura: IEEE, 2011. p. 19-20
10. Himona, S. et al. Sympol VR – A virtual reality law enforcement training simulator. Mediterranean Conference on Information Systems, 6., 2011
11. Ellis, C.A., Gibbs, S.J. and Rein, G.L. "Groupware - Some Issues and Experiences", *Communications of the ACM*, January 1991, Vol. 34, N. 1, p. 38-58
12. Ellis, C.A. An Evaluation Framework for Collaborative Systems, Colorado University Technical Report CU-CS-901-00, February, 2000.
13. Baker, K.; Greenberg, S.; Gutwin, C. Heuristic Evaluation of Groupware Based on the Mechanics of Collaboration. In: 8th IFIP Working Conference on Engineering for Human-Computer Interaction, 2001, Toronto, Canada.
14. Laurillau, Y., Nigay, L. Clover architecture for groupware. Conference on Computer-Supported Cooperative Work (CSCW). 2002. p 236-245.
15. Riva, G. "Applications of Virtual Environments in Medicine". *MIM – Methods of Information in Medicine*, vol. 42, n. 5, pp. 524-534, 2003.
16. Blas, N.D.; Poggi, C. "European virtual classrooms: building effective "virtual" educational experiences". *Virtual Reality, Springer 2007*, vol.11, n. 2-3, pp. 129-143.
17. Kirner, C. et al. Realidade Virtual: Conceitos e Tendências. São Paulo:Editora SENAC, 2004.
18. Capps M., McDowell, P, and Zyda M., "A future for entertainment-defense research collaboration," *IEEE Computer Graphics and Applications*, 2001, v. 21, n.1, pp. 37–43
19. JAIN, S.; McLEAN, C. *Integrated simulation and gaming architecture for incident management training. Proceedings of the 37th Winter Simulation Conference*, Orlando, Florida., pp. 904–913. 2005.
20. Lukosch, H., van Ruijven, T. and Verbraeck, A. (2012) The participatory design of a simulation training game, *WSC '12: Proceedings of the Winter Simulation Conference*.
21. CBM-SC, Apostila para Preparação do Brigadista Particular, 2014.
22. Kalawsky, R.S. "The science of virtual reality and virtual environments", Ed. Addison-Wesley, 405 pp., 1993.
23. Bennett C.; Anderson G.; Brady J. Improving Situational Awareness Training for Patriot Radar Operators. In: IEEE Aerospace Conference, 2010, Big Sky, MT, 2010, pp. 1-7.
24. MOSHELL, J.M. et al. "Dynamic terrain", Simulation, pp. 29-40, vol. 62, n. 1, January, 1994